

# **An ATM WAN for CSCW applications: The BETEUS Network (Broadband Exchange for Trans-European USage)**

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## **Abstract**

Multimedia is an important issue that drives the request for ATM (Asynchronous Transfer Mode) communication. The usage of multimedia features in a *collaborative work environment* is the core of BETEUS - Broadband Exchange for Trans-European USage.

In this paper we discuss the design and implementation of the BETEUS communication platform. BETEUS is a european project funded by the EC which is aiming at providing a platform for the support of CSCW applications such as tele-teaching, tele-meeting or tele-seminar. The communication platform is the part of the overall BETEUS platform that provides end-to-end connectivity between BETEUS sites. The realization of the communication platform is constrained by the services available on the European ATM pilot.

The development of the BETEUS application platform is independent from the actual support of the underlying communication infrastructure. Although all BETEUS user sites run FORE ATM 200 switches, this was not obvious when the design of the communication platform was started. But, at that time, it was apparent that IP connectivity was available for all partners either directly over ATM or SMDS (Switched Multimegabit Data Service). The communication platform can be extended so that IP multicast facilities can be used for point-to-multipoint communication as is requested by tele-teaching applications.

The paper discusses the services offered by the European ATM pilot. Since the BETEUS communication platform is designed to provide reliable connectivity between BETEUS user sites, sites are connected by a fully meshed network using ATM VPs (Virtual Path), i.e. *permanent virtual channels (PVC)*. PVCs are based on the semi-permanent virtual path service (Section 2.2). Such a service has been considered most appropriate with respect to the design considerations of the BETEUS communication platform

# 1 Introduction

Multimedia is an important issue that drives the request for ATM (Asynchronous Transfer Mode) communication. The usage of multimedia features in a *collaborative work environment* is the core of BETEUS - Broadband Exchange for Trans-European USage [1]. The set of functions that has been developed in the project are best captured by the so-called *virtual community paradigm*. A community is basically a group of people with common interests that participate in a set of operations towards reaching a common goal. In the case of BETEUS the operations can consist of *working, teaching, learning, project management* and *technical design* [2]. The virtuality of the community is due to the fact that the people who participate in the common operations are located in geographically distant locations. The BETEUS communication platform provides the services required for interconnecting distant locations to establish the virtual community [3].

The BETEUS communication platform is built on top of the European ATM pilot network. As services both end-to-end native ATM and IP connectivity are provided. In its current implementation, BETEUS applications can communicate via sockets [4]. This decision has been taken for practical reasons. Firstly, the development of the BETEUS application platform is thus independent from the actual support of the underlying communication infrastructure. Although all BETEUS user sites now run FORE ATM switches [5], this was not obvious when the design of the communication platform was started. But, at that time, it was apparent that IP connectivity was available for all partners either directly over ATM [6] [7] or SMDS (Switched Multimegabit Data Service). Secondly, the communication platform can be extended so that IP multicast facilities [8] can be used for point-to-multipoint communication as is requested by tele-teaching applications. Thirdly, sockets are flexible in the sense that a different network technology may be used for the support of BETEUS applications (although this is not an issue in the BETEUS project).

The paper is structured as follows: Section 2 discusses the services offered by the European ATM pilot. Since the BETEUS communication platform is designed to provide reliable connectivity between BETEUS user sites, sites are connected by a fully meshed network using ATM VPs (Virtual Path), i.e. *permanent virtual channels (PVC)*. PVCs are based on the semi-permanent virtual path service (Section 2.2). Another topology tested is based on a centralized architecture providing IP multicast functionalities. Such a service has been considered most appropriate with respect to the design considerations of the BETEUS communication platform (Section 3). The realization of the BETEUS communication platform is discussed in Section 4. We give details on the overall network topology, the local site configurations (Section 3.3), multicast (Section ) and interconnection field trials with IBER (Section 3.5). We conclude with an assessment of our achievements.

## 2 The WAN based on European ATM Pilot

The ATM-Pilot network, result of an agreement by nearly all European telecom operators (MoU), is the basis for the international broadband interconnectivity of the Austrian NH to other such facilities within Europe.

The original aim of the ATM-Pilot was to test the proposed international ETSI and ITU-T standards as well as relevant EURESCOM specifications.

This established European ATM infrastructure is the pre-requisite to perform trials and demonstrations of European projects on an international scale.

In the context of the BETEUS project (a follow up to Betel [9]), ATM Pilot network is used to provide end-to-end pure ATM communication between BETEUS sites: CERN in Geneva (Switzerland), EPFL (Switzerland), ETHZ (Switzerland), EURECOM in Sophia Antipolis (France), KTH in Stockholm (Sweden) and TUB in Berlin (Germany). The goal of the communication infrastructure is to run multipoint multimedia tele-teaching applications such as *distributed classroom*, *tele-seminar* and *multimedia document archival and retrieval*.

### 2.1 ATM Pilot Network Topology

The ATM Pilot represents the first step towards B-ISDN [10]. The ATM links are configured via the existing SDH/PDH transmission infrastructure with a bandwidth of 34 Mbit/s or 155 Mbit/s (Figure 1).

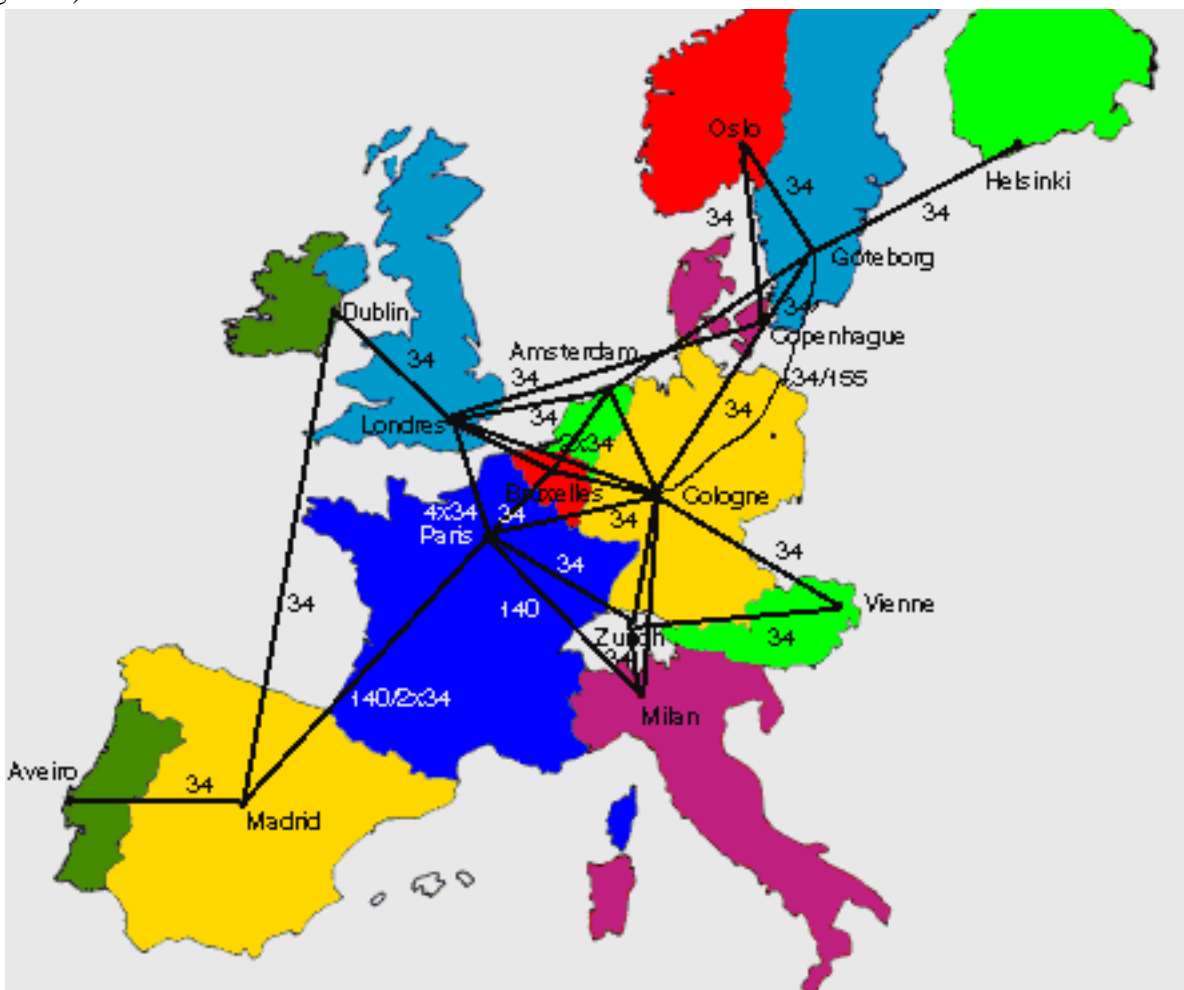


Figure 1: ATM Pilot backbone

## 2.2 Semi-permanent Virtual Path Service (SVPS)

This service allows communication in both directions between reference points  $T_B/V_B$  (Figure 2). The establishment mode are either reserved (occasional or periodic) or permanent. Only the physical layer and the ATM layer are defined. Higher layers have end-to-end significance and can be chosen according to the needs of the application (e.g. proprietary protocols). The provision of SVPS is based on virtual path (VP) connections in the ATM network. The physical bandwidth at the access points is defined by the existing interfaces. For the purpose of the ATM pilot, two interfaces are defined at 34 Mbit/s (E3 interface) and 155 Mbit/s (STM-1 interface). Both kinds of interfaces are used in the BETEUS communication platform.

The parameter “peak cell rate” is associated with each VP. The peak cell rate corresponds to the usable transfer bit rate, from the user’s point of view, divided by the payload of an ATM cell in bits ( $48 * 8$ ). A user can subscribe any value of the usable information transfer peak cell rate that is available at the user interface. The BETEUS communication platform is implemented using the SVPS.

## 3 BETEUS Communication Platform

### 3.1 Design Considerations

The communication platform has been designed taking the following considerations into account: the networking configuration and the application requirements.

- Networking Considerations

Since the BETEUS communication platform is built on top of the ATM pilot network, the design decisions must take into account the services offered by the ATM pilot (as described in Section 2) and the variations of the network configurations in the local sites (Section 3.3). For instance: The maximum bandwidth is 34 Mbit/s for most of the BETEUS partners (except ETHZ which is operating two STM-1 links). Only semi-permanent virtual path services are available for the ATM pilot users. ATM signalling and point-to-multipoint services at the ATM level are not provided by the ATM pilot, neither the switched virtual connections (SVC). This has consequences for the provision of multicast in the BETEUS communication platform (Section ).

- BETEUS Application Requirements

The BETEUS applications are *interactive multimedia applications*. This class of applications imposes stringent network requirements as summarized as follows: guaranteed throughput, bounded end-to-end delay, low packet loss, connection oriented transport, multicast and support for real-time data services.

BETEUS application has different bandwidth requirements depending on the different scenarios. The aim of the BETEUS application is to provide multimedia communication to a virtual community of users. The motivation of this virtual community may be teleteaching, tele-meeting (Figure 2) or tele-seminar. for each usage correspond one scenario.

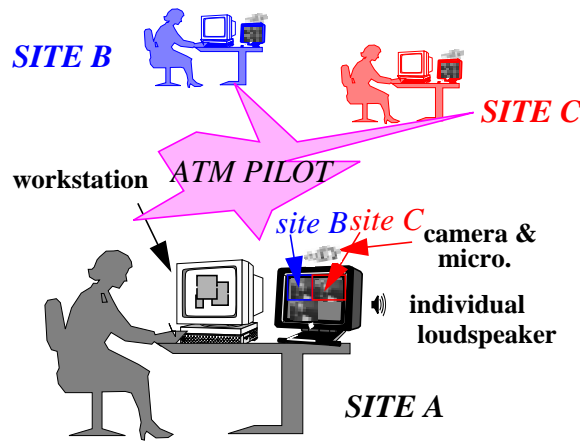


Figure 2: Tele-meeting scenario

In the distributed classroom scenario every distributed classroom sends its own classroom view to all other classes and receives classroom views from them. Images of the speaker are also distributed to other classrooms where he/she is not physically present. Distributed classroom has predictable bandwidth requirements since the scenario and the maximum number of sites involved are generally fixed during the session. Teleseminar, on the other hand, is quite more demanding with respect to bandwidth requirements, since users may freely join and leave sessions. However, the bandwidth required for connecting *two* sites can (more or less) accurately be estimated. For running the BETEUS scenarios the bandwidth of a connection has been estimated to 3 Mbit/s based on the following observations:

Low quality video streams at about 512 Kbit/s of a quarter of PAL resolution and with 9 frames per second (fps) is used for classroom views, while the speaker images are at the same resolution but use higher quality video streams at 25 fps (1,5 Mbit/s).

Assuming use of speaker quality for audio at 64 Kbit/s and shared workspace application at 60 Kbit/s data exchange rate, the total bandwidth (including shared workspace and the high quality video connections needed for the speaker) is less than 3 Mbit/s per connection.

Experiences have shown that the described application requirements are met by the BETEUS communication platform. A bottleneck has been some of the workstations used. This problem has been solved by a load-balancing between workstations.

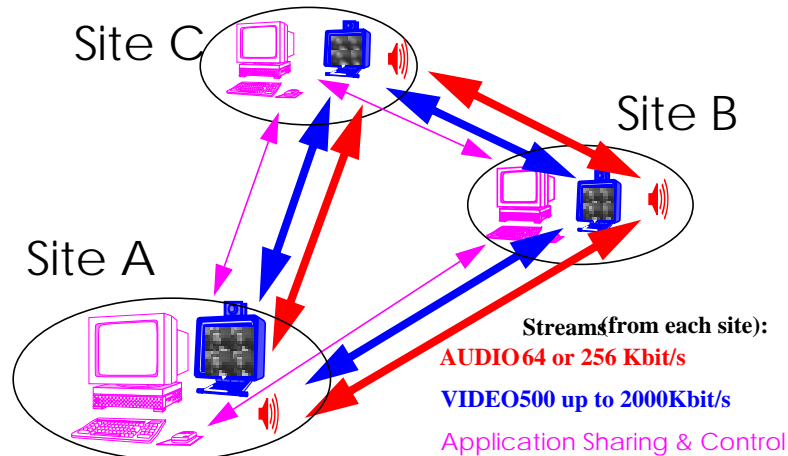


Figure 3: Streams in Tele-meeting Scenario

### 3.2 Description of the BETEUS Communication Platform

The BETEUS communication platform is built on top of the ATM Pilot. Two topologies were tested: A fully meshed VP network, called BETEUS network (Figure 4) and a starred VP network called IBER/BETEUS network.

#### 3.2.1 The BETEUS topology

Since access to the ATM pilot was not possible for all partners at the same time, the fully meshed network was the optimum solution for launching tests as early as possible. Each site is connected through the ATM pilot with the other five sites by means of bi-directional VPs. The peak bandwidth allocated for each VP is 3 Mbit/s. Access to the ATM pilot is made on the local ATM switches through E3 34 Mbit/s PDH interfaces (at EURECOM, EPFL, CERN, TUB) or STM-1 155Mbit/s single mode fibre interfaces (at ETHZ).

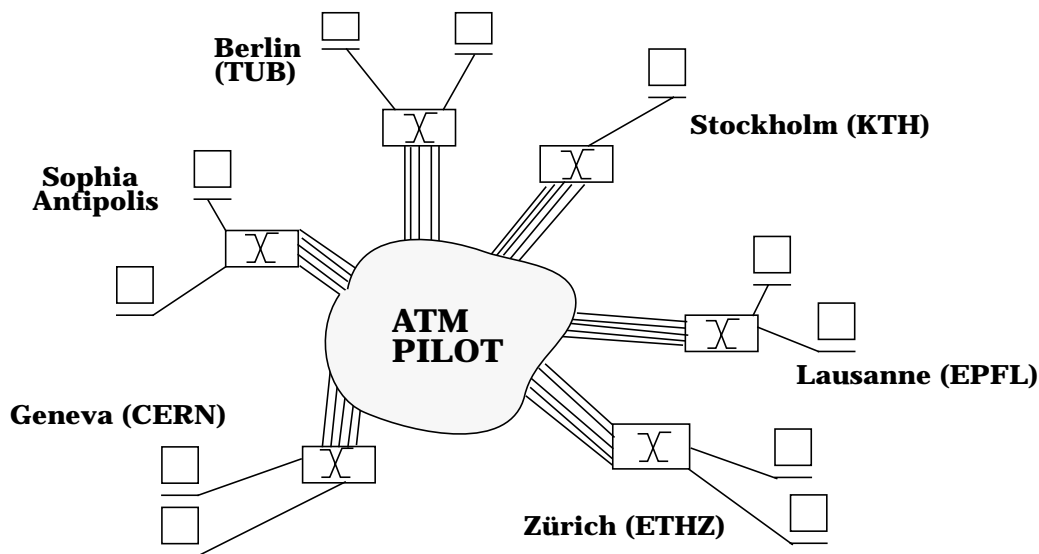


Figure 4: BETEUS Communication Platform Topology

#### 3.2.2 The BETEUS/IBER topology

It was a requirement from the EC to initiate a collaboration between the two RACE projects, BETEUS and IBER. The objective of this collaboration was to physically interconnect their networks in order to broadcast a IDC<sup>1</sup> conference.

The BETEUS/IBER network has a star topology constructed using point to point bidirectional symmetric ATM connections. In this configuration, sites are connected by one point to point bi-directional symmetric ATM link (allocated in only one VP) with 6 Mbit/s to the root (root is the TID site at Madrid).

Another difference is the addressing scheme. The network uses a set of addresses which are picked from the public class B IP network. Each site is assigned a IP address and has entry points connecting to the ATM WAN either directly with a workstation or via a router. The IP address of the connection to the WAN is picked of the IP addresses block allocated to the site.

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1. IDC: International Distributed Conference

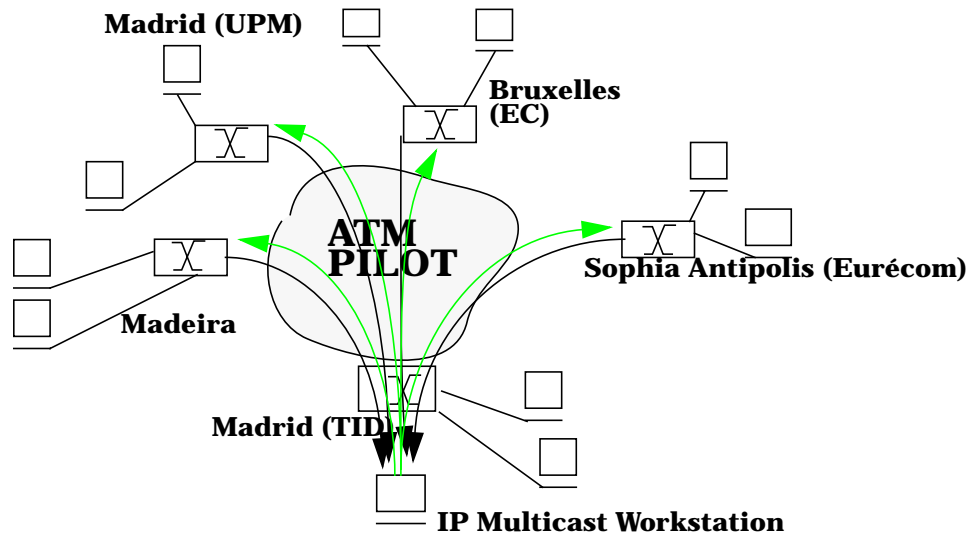


Figure 5: BETEUS/IBER Network topology

### 3.3 Local Site Configuration

#### 3.3.1 Hardware equipment

ASX-200 ATM switches from FORE Systems [5] with the ForeThought software version 3.2.0 equipped each site. These ATM switches are directly connected to the ATM pilot by a E3 or STM-1 interface.

Locally the workstations, SPARC 10 or SPARC 20, are connected to the ASX-200 switch by 100 Mbit/s TAXI interfaces. These workstations are equipped with PARALLAX video boards (Motion JPEG) and with a SBA-200 ATM adapter cards from FORE Systems [11] (Figure 6). The workstations are running SunOS 4.1.3, ForeThought 3.0.2, SNMP agents and IP multicast extensions version 3.3. The workstations are multi-homed on ATM and Ethernet networks because some services such as name servers or applications servers are located on the ETHERNET LAN. All the ATM traffic generated on the ATM Pilot is sent over ATM Adaptation Layer 5.

#### 3.3.2 VP configuration of the BETEUS network

As the ATM Pilot provides semi permanent VPs, we have to configure the switches using VP num-

Table 1: VP Identifier Allocation

	EURECOM	EPFL	ETHZ	CERN	TUB
EURECOM		4	2	71	6
EPFL	4		2	8	3
ETHZ	4	3		8	2
CERN	71	9	8		4
TUB	114	122	121	167	

bers given by the local operator.

For example, the EURECOM ATM switch is configured to send all traffic to EPFL on virtual path

identifier (VPI) 4. At EPFL, all traffic to ETHZ is sent through VPI 2. All VPs have a cell delay variation value of 106 cells and 3 Mbit/s (8310 cells) bandwidth assigned which means that  $5 * 3 = 15$  Mbit/s are allocated per physical link.

France Telecom for EURECOM, Swiss PTT for EPFL, ETHZ, CERN and Deutsche Telecom for TUB assigned the VPs depicted Table 1 to provide connectivity to the European ATM pilot.

### 3.3.3 VC Configuration of the BETEUS network

Each site keeps its own IP addressing schema. Currently, due to ForeThought limitations, there is no signalling used in the BETEUS communication platform (neither SPANS [12] nor Q.2931 nor UNI 3.x [13]). Signalling will be tested in the future with a new release of ForeThought. The BETEUS fields tests use at least two SPARC 10 workstations in every partners sites (Figure 6). The connections between workstations are set up manually by updating the ATM ARP tables. To have ATM connections between all workstations, we need to set up 4 virtual channels (VC) at each site (2 VCs per workstations). At site A, the workstation 1 sets up one VC 1/1 (see also Table 2) for workstation 1 at site B and one VC 1/2 for workstation 2 at site B. The workstation 2 has also 2 VCs (2/1 for workstation 1 at site B, 2/2 for workstation 2 at site B). The four VCs created for one specific destination are multiplexed onto the VPI set for the destination on the local ATM switch (Table 2 column VPI).

Table 2: VC/VP Allocation at EURECOM

From -> To	VC 1/1	VC1/2	VC2/1	VC2/2	VPI
Eurecom-> EPFL	120	121	125	126	4
Eurecom->ETHZ	140	141	145	146	2
Eurecom-> CERN	210	211	215	216	71
Eurecom-> TUB	130	131	135	136	6

Workstation 1 at EURECOM reaches workstation 1 in Zürich using VCI 140 and workstation 2 in Zürich using VCI 141.

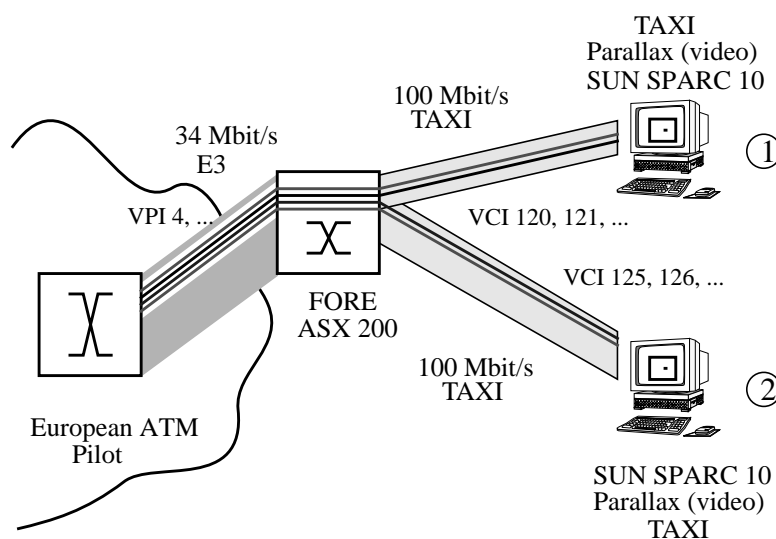


Figure 6: Example of Local Site VP/VC Configuration



### **3.3.4 VP configuration of the IBER/BETEUS network**

Each site has to established only one VP with the central site.

### **3.3.5 VC configuration of the IBER/BETEUS network**

Two networks are mapped on the VCs configuration, the unicast network and the multicast network. For the unicast network, two VCs per remote site are created, one from the site to the central site and another from the central site to the site. Concerning the multicast network, just one VC per direction is created between each site and the central site.

## **3.4 Multicast aspect**

Since the aim of the BETEUS application is to provide a multimedia communication support for a virtual community distributed in the different sites, the BETEUS communication platform has to support *multicast services* for point-to-multipoint connections. BETEUS applications must be able to send video, audio and data in the same time to several users in different sites.

### **3.4.1 Multicast Services**

Multicast services provide efficient utilization of network resources and the possibility to reach a group of recipients in a single data transfer. In principle, ATM can support applications with multicast services but currently, the ATM Pilot network does not provide any ATM multicast service. So what it can be done is an internal multicast service in the endpoint switches.

Using FORE Systems equipment and software, this can be done in different ways:

- by using IP multicast [14];
- by using ATM multicast with ForeThought application programming interface (API) developed by FORE Systems [11].

The use of ATM multicast using FORE API requires that application are written using this API and that SPANS (Simple Protocol for ATM Network Signalling) [12] is available.

IP multicast as defined in RFC 1112 [14] is supported by FORE ATM switches and performed by the switch hardware. It can be performed over switching virtual channels (SVC) as well as permanent virtual channels (PVC). Multicast SVCs are created using SPANS while there are two modes for the creation of multicast PVCs:

- A PVC can be created for every multicast group the host wishes to send traffic to.
- One PVC is created to transmitted traffic for all groups. This PVC is viewed as the default multicast PVC.

FORE switch implements a host group addressing feature, giving SPANS the capability to handle IP multicast traffic. When a host opens a connection to a group address, the switch to which the host is attached opens a point-to-multipoint connection to all members of the group.

Since BETEUS applications have to send data to several sites, multicast in BETEUS consists of making point-to-multipoint connection on different VPs on one port.

### **3.4.2 Restrictions**

A problem becomes evident in case when we try to set up such connections. The current ForeThought software version and the hardware modules used in the ATM switch allow only to multicast to VPs on different ports. Since all VPs to the other sites are on the same port, using this multicast

solution is impossible.

A new version of ForeThought (3.3.1) allows to do VP sharing which should allow multicast and signalling over the European ATM Pilot. This version enables traffic sharing on a per path basis. Sharing a single path is possible if the WAN link contains a single path (the WAN port can be used to share the path), but it is not the case for BETEUS. Sharing multiple paths (WAN links contains multiple paths) needs to have one free port (no physical link on it) per path. In this case, the WAN port should not be used for sharing. To share each path, each other port shares one path and “through paths” are created from these sharing ports to the WAN port. For example, with an E3 module with 4 ports, it should be possible to share 3 paths and make point-to-multipoint connections with 3 sites. One port of the E3 module is connected to the ATM pilot and contains VPIs x, y, z. The second port will share path x, the third one path y, and the last one path z. Unfortunately, this configuration has not yet been tested.

### 3.4.3 Alternatives for Providing Multicast

Due to the restrictions described above, other possibilities have been studied. One possibility would have been to have a central multicast host, which sends all receiving data to all partners. In principle, the advantage of such a solution is the low cost for having only one bi-directional link from each site to the multicast host. Since BETEUS applications are based on fully-meshed communications (each site has to receive traffic from all other sites), we could have the low cost advantage only if ATM providers are able to provide non-symmetric ATM links.

A solution with a central multicast host is impossible to implement because some components of the application (control and application sharing), running on top of the communication platform, need reliable multicast functionality.

### 3.4.4 Multicast in the BETEUS network

Within BETEUS we therefore have implemented a solution which has been easy in its realization but, on the other hand, requires a lot of resources on end-systems. The BETEUS solution is to implement multicast in the applications. For instance, a video stream is transmitted to several (more than one) remote sites by duplicating all video packets in the application (Figure 7). Quite obviously, this introduces an unnecessary load on the end-system which could be avoided if multicast would have been provided in the communication platform. The application does support also IP Multicast. This capability to manage IP multicast communications is mandatory over the IBER/BETEUS network.

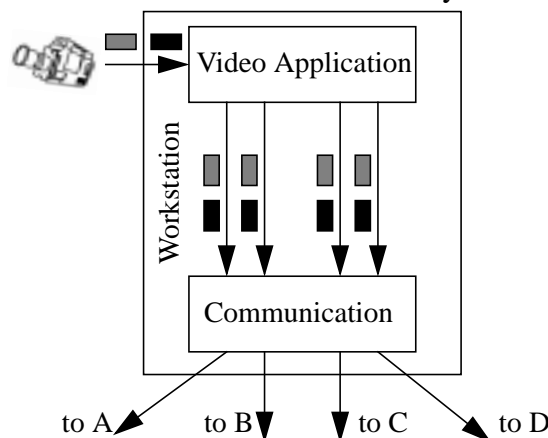


Figure 7: BETEUS Multicast Support

### **3.5 Multicast in the IBER/BETEUS Network**

The Unicast network has a hierarchical IP network that interconnect LANs at each site. The multicast network is used to distribute multimedia traffic encapsulated in IP datagrams with class D addresses. It is used a multicast workstation server (attached to a local ATM switch) which has been the destination of all incoming VCs from the leaves. The multicast workstation has to forward all incoming datagrams to a single point-to-multipoint output VC within the local ATM switch that replicates the cells to all outgoing VCs (root to leaves communication). Multicast IP addresses used by the BETEUS or IBER applications are 224.6.6.1 (Audio), 224.6.6.2 (Video), 224.6.6.3 (Control 1), 224.6.6.4 (Control 2). The additional configuration for the two BETEUS workstations at EURECOM connected to IBER is described hereafter.

- One additional VP (VPI 12) with 6 Mbit/s peak bandwidth has been created on the EURECOM switch.
- A unicast outgoing PVC of 1 Mbit/s has been created on each workstation for connection to the IBER CISCO router.
- Incoming PVCs from DIT have been created on each workstation.
- One default outgoing PVC and one incoming PVC for multicast have also been created on one workstation.
- A static route has been defined to reach the IBER IP logical network through the CISCO router for which a PVC has been established.
- The multicast route for multicast IP addresses 224.6.6 through the CISCO router has been defined.

Successful tests using both ISABEL and BETEUS applications have been made with the unicast and the multicast network. Further tests are planned.

## **4 Experiences**

BETEUS Network was operational since May 1995. The tests were performed each tuesday morning from 9:00 to 13:00. The short duration of the time slots implied to be very efficient in term of organization and coordination.

The organisation of the seance consist of sending the day before, to all the partners a E-mail (via Internet) explaining both the objective and the planning.

Coordination is insured by two ways, telephone and Internet, using "wb", a witheboard application, running over IP multicast (Mbone). Using wb, each partner access to a common witheboard in a X11 window in order to exchange messages or graphics with the other participants.

### **4.1 Connectivity tests**

The first tests done on the BETEUS communication platform have been the connectivity tests. The PING utility has been used to test the connectivity between sites. PING sends ICMP echo packets to a destination host. PING is used in testing, managing and measuring network performance. It is used primarily to detect connectivity problems. It gives information on round trip times (RTT) and packets losses. The RTT with 64 bytes packets is 30 ms between France (EURECOM) and Switzerland while the RTT is 4 ms between Swiss sites.

The second kind of tests done at the set up of the BETEUS communication platform has been those

using a program called “api\_pvc” provided by FORE Systems. This tool tests the connectivity between BETEUS sites in addition to enabling transfer of ATM cells. This program is written using the FORE Systems proprietary API. It is used between a sender and a receiver. Both VP and VC should have been set up manually. “api\_pvc” enables to test communication between sites with different packets sizes, different bit rates, different ATM adaptation layers, different numbers of packets. The program calculates the throughput between two sites.

## **4.2 Tests using the BETEUS application**

After using testing the network for validating the local site configurations, the BETEUS applications have been tested and optimization of the BETEUS communication platform have been performed.

At first we tested Standard the different components of the application, audio processing, video processing and application sharing. In a second time, we tested the overall of the application including the global control of the platform.

## **4.3 Real usage of the BETEUS application**

### **4.3.1 Internal technical meetings**

Some internal technical project meetings were organized over the BETEUS network. The BETEUS application was used with the telemeeting scenario. With this scenario the participant can take part in any unformal discussions, can prepare a common document, using a word proceesing software and the sharing application facilities.

### **4.3.2 Distributed conference in Madeira (Nov. 17)**

This conference was initiated by BETEUS project and then joined by IBER<sup>1</sup> project as a sponsor to host the main centre for the conference at Madeira in Portugal. Madeira was a very appropriate location to demonstrate Multimedia Applications for Distributed Events In Remote Access (MADEIRA) as the name stands. The other remote locations involved were Sophia Antipolis (France), University of Madrid and Telefonica I+D (Spain) and European Host in Brussels (Belgium). This event was also the first event to demonstrate two independent multimedia applications (ISABEL and Beteus) developed in European research framework.

### **4.3.3 Teleteaching EPFL-ETHZ-EURECOM (Nov. 7 and 21)**

This experiment consists of remote courses broadcast using the BETEUS network and application platforms. In November, a course on Acoustics & Communications, given by professor Rossi, was broadcast from EPFL to the other sites.

## **5 Conclusions**

In this paper we have discussed the realization of the BETEUS communication platform which is used in the BETEUS project to support distributed multimedia applications like distributed classroom, tele-meeting and multimedia document archival and retrieval. We have started out from a discussion of ATM network services offered by the public network operators. It has turned out that some essential features which would have been advantageous for the realization of the BETEUS

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1. IBER is a european project funded by the EC (DG XIII)

communication platform have not been available. We tested two different architectures: the BETEUS topology, providing a fully meshed connectivity and a second one, the IBER/BETEUS topology which is a centralized solution. Using this last network, the multicast functionality is performed by a workstation on the central site using IP multicast services. Concerning the BETEUS network, as no multicast functionality was offered by the network, we have decided to provide for an alternative. Providing multicast services by the BETEUS communication platform rather than by the BETEUS application is still an unresolved issue. Although a new ATM switch software release has been provided by FORE, no optimal solution is available. Nonetheless, we have been able to implement a communication platform which is stable, flexible and scalable. Furthermore, the important application requirements (as discussed in Section 3) are fulfilled. Five sites (i.e. CERN, EPFL, ETHZ, EURECOM and TUB) have been connected. All BETEUS scenarios are supported and tests have been conducted to interconnect to IBER.

We expect that a fully operational ATM infrastructure providing all ATM services, particularly signalling and multicast, will improve utilization of resources in the BETEUS community. For instance, we expect that the error prone manual installation of VP and VC connections will be improved by ATM signalling functions.

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